# AI Programming by Children using Snap! Block Programming in a Developing Country

Ken Kahn[1] , Rani Megasari [2] , Erna Piantari[2] and Enjun Junaeti[2]

[1] Department of Education, University of Oxford, 15 Gardens, Oxford, UK
[2] Department of Computer Science Education, Universitas Pendidikan Indonesia, Indonesia
toontalk@gmail.com, magasari@upi.edu, erna.piantari@upi.edu, enjun@upi.edu

**Abstract.** The development of human civilization today can't be separated from the Artificial Intelligence. To prepare for this, early education on Artificial intelligent should be done. Some activities have been done to support students making AI programs, for example Google AIY, Machine Learning for Kids website, the Wolfram Language, and the eCraft2Learn project. One of the new block programming languages Snap! has been extended to provide an easy-to-use interface that provides AI cloud services as well as other AI functions. However, there is little research about AI programming learning for children in developing countries. This paper presents how the learning of AI programming using Snap! programming in Indonesia. The learning process was evaluated with 40 Senior High Schools and Vocational students. 84% students had some basic programming experience but others had none. 70% students who had basic programming experience felt that AI programming using Snap! was easy to understand, yet the students with no programming experience found it difficult. Even though mostly the students can answer the evaluation question about how AI works and all the students were keen on creating AI programs using Snap!. We concluded that Snap! programing worked to introduce AI to children and has encouraged children to explore AI programming. However, some improvements are required to improve the learning process of AI programing using Snap! in developing country. The improvements are presented in this paper as the result of this research.

**Keywords:** AI programming, Block programming, Snap!, Education, Computer Science Education.

## 1 Introduction

Nowadays, AI slogan is becoming more popular without exception in developing country. Many services are developed by including AI features with the aims to increase the value of product and to interest many users from adults to children such as for tourism planning[1], for educational robotics [2], for chatting[3], and for daily mail reading [4]. Interestingly, even though AI services have become ubiquitous as in conversational assistants (Google Assistant, Siri, Cortana, etc), vision apps (driverless cars, security, x-ray analysis, character recognition, etc**)**, text analysis (news article generation, sum-

marizing, sentiment analysis), and machine learning (translation, game playing, finance, medicine), not everyone knows about AI benefit, so they just use the device which can support AI application in an ordinary way without utilizing the AI features. Using an advanced technology product without adequate knowledge can cause its utilization to be non-optimal. Especially in developing country, this problem can cause a domino effect to other fields which needs AI in their business and also widen the gap of AI technology development in competition with developed country.

Introducing AI to children is a proper strategy to prepare an AI-capable generation. AI for children already existed in 1977 [5]. Since habit can cause deliberate goal pursuit [6], assisting children in using AI features has a purpose to make them easy and enjoy AI, accustomed to use AI, then become better motivated and empowered to produce very capable artefacts. However, AI itself has three aspects that must be known to be able to understand AI, based on an agent illustration to describe AI [7], which are agent environment, agent perception, and agent action. Therefore, the most possible way to introduce AI to children is by helping them be in touch with AI features and giving them the experience of trying AI programming.

Block-based programming is present as programming tool besides text-based programming. It has become increasingly common in high school because of its ease-of-use characteristics such as including the natural language description of blocks, the drag-and-drop composition interaction, and the ease of browsing the language [8]. Snap! is one of the programming tools which provides child-friendly programming interfaces to AI Cloud services [9]. Through its library such as eCraft2Learn, children can learn about behavior in the process perceptive robots and apps to encounter understanding of AI. Block-based programming can also be used to improve computational thinking of children by using follow and giving them instructions to follow [10].

Indonesia which is as one of developing country in southeast Asia has bonus demography in the form of very large population of citizen with the age of 15-64 years. Due to the influence of brands on consumer behavior [11], this country should pay attention to educate its nation's generation especially about their digital skill to meet the globalization challenge. As a preliminary research, this paper reports findings from workshops on AI Programming for Children which is held on March and April 2018 by Computer Science Education Department, Indonesia University of Education. Further works will talk about problem investigation in learning process based on the current result.

## 2 Related Work

There are some works that has be done to introduce Artificial Intelligent in early education level. Logo has initialized this work that allows children to learn about AI by constructing AI programs [5][12][27]. After decades, there were some activities that were done to support students in making programs from Stephen Wolfram [13]. Wolfram built an technology environment that allows student from elementary school to graduate and beyond to learn and create programs from simple to AI programs. The programming language that is used is Wolfram Language that is integrated with some

automated machine learning. Therefore, it's making state of the art machine learning in a full range of applications accessible even to non-experts.

Moreover, in early 2018, as one of the biggest technology company, Google being offering AIY project as a service to facilitate students learn about AI in 2018. The learning concept that used in this project is learning by construction that is called 'Do-it-yourself artificial intelligent'. With AIY kits, students can build devices that see, speak, and understand. Furthermore, Lane uses programming rather than kits to facilitate children learning about AI. Lane created the website service 'Machine Learning for Kids' that uses extension to the popular Scratch programming environment to teach the basic machine learning to children. Scratch [14] is a visual programming language. In this environment, drag and drop palettes provide access to primitive program elements [14]. This programming language was designed to help children to think creatively, reason systematically and work collaboratively by programming in which no keyboard skills is needed.

eCraft2learn is another project that is designed to help children to learn about AI. eCraft2learn used Snap! and new additional blocks to Snap! visual programming language [14] that provide easy-to-use interface to both AI cloud services and deep learning functionality. Interactive learning materials have been developed [15] Project eCraft2learn uses Snap! due to it being a powerful language that support first-class data structure and functions, and it's easy to define new block using JavaScript without touching the source code. Beside that Snap! is a block programming that runs in every modern browser. Therefore, it'll help students to use it [16].

This paper shows how the AI learning process is done in Indonesia. As a developing country, mostly students in Indonesia are not familiar with programming, even though some students have learned about text-based programming. In this activity, we are focus on how students learn about Artificial Intelligence, so that we want to hide some details of programming problem to help students to understand about AI. However, in this learning process we used learning by construction approach in which this approach is suitable to encourage individual to be more creative [17]. This approach agrees with situated learning theory, which emphasizes that the idea of cognitive support learning by enabling students to acquire, develop and use cognitive tools [19]. Accordingly, programming is needed as a tool to implement learning by constructions.

There have been some reports that used block programming language for introduction programming education [20] [21] [22]. The result of some reports showed that block-based programming feels familiar to beginners and help students to understand how to create a simple program. eCraft2learn project is provided to learn AI using Snap! as a based-block programming language. Hence we used eCraft2learn to help in this learning process.

# 3 Methodology

## 3.1 Participants

The experiments of the learning process were executed by involving 40 Senior High Schools and Vocational students. Students consisted of 15 women and 25 men between the ages of 16 and 17 years. Based on existing samples, 100% of students are accustomed to using computers for doing homework, gaming, watching video, doing programming, or designing, and for 87.5% students it's was the first time to learn AI. Furthermore, 87.5% of students are already familiar with programming, and 95% of students are accustomed to using AI applications, such as: ok google, google translate, Cortana Windows 10, Siri, and speech recognition app.

## 3.2 Design Learning Process

Generally, the learning process scenario is designed using learning by construction concept. Snap! Block programming is used as a construction tool that can help students more easily to follow the learning process even though they are not proficient in programming. The learning scenario of this research is presented on Fig 1.

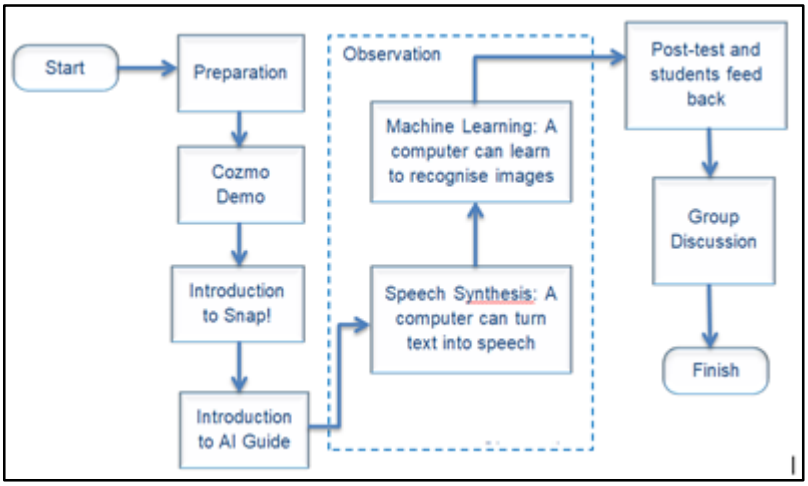


**Fig 1.** Learning process scenario designed for the learning of AI programming using Snap! programming.

**Preparation.** This phase is a process to prepare for learning process so that can be run in accordance with the planned activities. The preparation that is done are:

1. Preparing the computer for each student can connect to Internet.
2. Set the student's position so that he or she can work individually but not limit the student to still be able to discuss with their friends.

Some problems that may occur during the learning process are technical problems such as network or computer installation, so that some instructors who will help in case of technical problems are involved in the learning process.

**Introduction to Students.** During this phase students discuss about examples of AI applications. Then Cozmo was demonstrated to attract students' interest and attention to the learning activities to be undertaken. Prior to entry into the material, students were given a brief explanation of Snap! And how to use AI guide. Then students were given an explanation and demonstration of the material on speech synthesis, i.e. how a computer can turn text into speech.

**Learning Process.** Artificial Intelligence refers to how to make a machine or computer acts like a human. Some human abilities that AI has are the ability to interact with other objects and the ability to learn about environment. In this lesson, students will learn about how to use a computer speech to interact with other objects using Speech Synthesis and how computer can learn about environment by Machine Learning Process. In every lesson, students will be encouraged to try and construct a simple process of computer speech and learning using Snap! Block programming.

*Speech Synthesis.* In this phase, student learn about how use a simple block in Snap! that is used to speak (see Fig 2). This block allows students to explore how is the speech process is done by computers. Some speech aspects that students could control are tone, pitch, volume, rate and language.

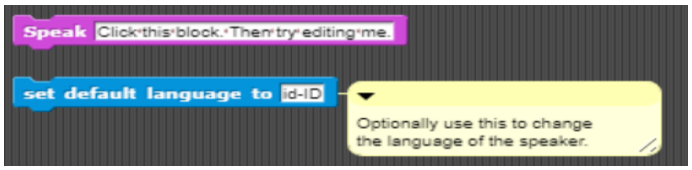


**Fig. 2.** Simple Snap! Block for Speech

In this lesson students tried to make their own sentences using English or Indonesian language and write in Speak Block. By clicking the block, then the computer will speak the sentences that was written by student. To understand how computers process the sentences, then the student has been encouraged to do an experiment about 'Heteronyms Problem'. Students tried to write words that mean and sound different but are spelled the same. For example, student wrote 'read' in two kinds of sentences. First sentence is 'I will read a book' and the second sentence is 'Yesterday I read a book'. Then the students will observe the different voices and how the computer speaks by experimentation.

*Machine Learning.* In this lesson the student tried some procedures about how computers learn. Snap! provides some blocks to do machine learning process. However, at the time of doing this learning process, machine learning blocks in Snap! are limited to images. Therefore, student learn about how a block in Snap! uses image from a camera to start machine learning process. There are two main processes in machine learning that are training and testing. The figure below is a Snap! Block is used for training and testing. To understand how training and testing processes in machine learning are, students did two experiment about machine learning using a simple Snap! program.

1. Simple program using image labels

In these experiments, students learn to control a movement of image labels using hand and body movement. Student train the computer to recognize the control by image from camera. In one experiment they train the system to recognize which way one is leaning. And in the other which way a finger is pointing. Fig.3 is a Snap! block that is used for training process.

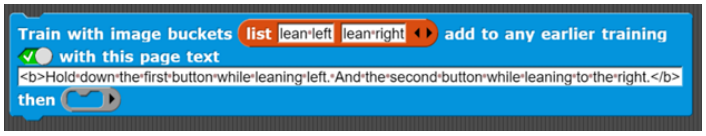


**Fig. 3.** Block Snap! for training process

When the 'Train block' runs, a tab will be launched for capturing image from camera to train (see Fig.4).


**Fig. 4.** Capturing image for training process

This interface (see Fig.4) makes the training process easier for student to understand. After training, the student did testing using this interface to discover how confident system was. After that then the student tried to give a command to the computer using image by camera.

2. Simple program about rock paper scissors game

Another experiment is to train computer to know another command for rock paper and scissors game. During the previous experiments students used two commands and the computer should recognize every command by camera image. In this experiment student used four image categories, i.e. rock, paper, scissors, and other.

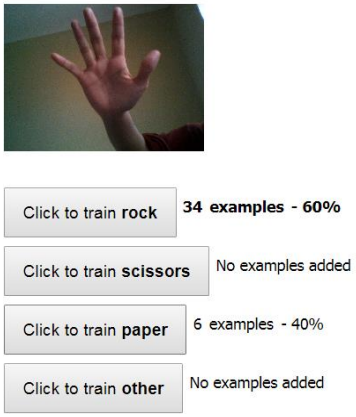


***Fig. 5.*** *Training process for rock, paper and scissor games*

After the training process, the students tried to play the game which uses camera imagines as an input. Afterwards the students compare their result with their friend's then they observe if there are different results.

.

**Observation and Measurement.** The evaluation of the learning process is done in two ways that are by evaluation testing and observation. After the learning process, the evaluation is done to measure their understanding of AI that has been described generally and their understanding based on the Artificial Intelligence aspects: environment of agent, agent perceptions, and agent actions. Due to efficiency of reliability criterion measures [23], essay tests were conducted in this phase.

The observation is done during the learning process. The students were observed based on 6 (six) aspects: student's attention to learning; student interest in lessons; student's activity; student's eagerness to learn; the learning atmosphere; and circumstances of orderly learning. Observations were conducted by four observers, so one observer observed eight students. In addition, they are also required to provide feedback on the learning process that has been done in the form of short answer questions.

**Data Analysis.** The research was conducted to evaluate the learning of AI programming using the Snap! Programming language in Indonesia using mixed methods approach sequential exploratory design[24].

The qualitative methods ware used to describe learning activities during the learning process and to explain what indicators of understanding students have learned afterwards. The qualitative data was presented to support the quantitative data that had been gathered.

# 4 Result and Discussion

## 4.1 Result

**AI Understanding.** In general, with their learning and being knowledgeable about how animals and people see, hear and learn, students can already be said to have some understanding of AI. From the answers given by the students during the test, 77.5 % of students indicated that they understand AI. Based on the aspects: environment of agent, agent perception, and agent action, students understanding of AI as follow:

1. Agent environment
   a) In speech synthesis, students already know that AI programs can control the sound aspect such as: language, speed of voice, tone, pitch, volume, accent, and gender of sound issued by computer. However, only a quarter of students answered correctly, while 55% of students could mention one or two speech aspects that could be controlled by the AI program, and the rest did not know. Furthermore, almost half of the students know that a computer could make a mistake in speech caused by noise, language setting, character usage in the text such as: [, |, and /, could not differentiate homophones in Indonesian language, even though they just mentioned one of them.
   b) In machine learning, more than three quarters of students know a computer could make a mistake to recognize picture after it was trained caused by:
      1) The computer did not detect what were conveyed
      2) Error or lack of clarity in introducing the objects or process
      3) Incorrect programming
      4) Noise
      5) Limitations of object in training process
      6) Resemblance of objects in computer training to recognize two or more different objects
      7) The training tools usage did not work properly

2. Agent Perceptions
   90% of the students stated that a computer speaks by recognizing the input text from the user using a keyboard, then it will speak according to the text input. In addition, more than half of the students (67%) were able to provide near-close perceptions of how computer learning works. They mention that the computer can learn using learning machine, i.e. the computer is given some program (instruction) to recognize the movements using image of the samples which was captured by camera in the computer. However, the other students have not been able to deduce how computers learn.

3. Agent Actions
   The deduce students' understanding of the aspects of agent actions by viewing the ability of students to identify the benefits and dangers of speech synthesis

and machine learning. The following Table 1 gives a summary about students' test answers about the benefits and dangers of speech synthesis and machine learning.

**Table 1.** Summary about student's answers

| | | |
|---|---|---|
| Speech synthesis | Benefits | 1. Help people who cannot read (e.g., blind people) to listen to some words from computers<br>2. Help people to communicate with others<br>3. Help people to translate and know the correct accent (English accent/another language)<br>4. Facilitate people in pronouncing or spelling a language<br>5. Facilitate in search engine and reduce typos.<br>6. Helping a child who is learning to talk<br>7. Helping in work related to medical and finance<br>8. Time efficiency<br>9. Making it easier to perform a text-related operation such as giving a search command operation or even sending a message |
| Machine learning | Benefits | 1. Reduce human work<br>2. Work and learn easier |
| | Dangers | 1. Lack of social community<br>2. Replace human (some people losing)<br>3. Harmful (error operation)<br>4. Misuse<br>5. Making people lazy |

Most of the students giving the same answer for the benefits and the dangers of machine learning. Almost no students did not know (gave no answers) about the benefits of machine learning. 40% of students stated that machine learning has no side effects to humans, for 10% it did, and the remaining did not respond.

**Background and the Student Enjoyment of Learning AI using Snap!.** We identified the relation between student's background and student's enjoyment of learning process. Mostly the students enjoyed the learning process. Data in Table 2 shows that all students who have ever studied about AI enjoy the learning process and only one student who didn't enjoy the learning process.

**Table 2** Relation between enjoyable and student's background

| | | First Time Learning AI | |
|---|---|---|---|
| | | Yes | No |
| Enjoy the Workshop | Yes | 34 | 5 |
| | No | 1 | 0 |

Table 3 shows that more than 40% students stated that it was easy, 7% students admitted that machine learning is difficult but speech synthesis is easy, 15 % students admitted that machine learning is easy but speech synthesis is difficult and the rest said both were difficult. By that data, we can identify that more students admitted that machine learning is easier that speech synthesis.

**Table 3.** Degree of difficulty admitted by student for each lesson

| | | Speech Synthesis | |
|---|---|---|---|
| | | Easy | Difficult |
| Machine Learning | Easy | 17 | 6 |
| | Difficult | 3 | 9 |

Nevertheless, a further 33 students or 82.5% students were interested and motivated to make the AI program by using Snap!, Students have been able to imagine AI products that they could create. Mostly students want to create games, text-to-speech app, a small robot which can help, a picture that moves by itself, speech learning app for baby, automatic lock door, anime, a Jarvis, an AI program that can search for lost motor or car keys with mobile app, pinball with nitros, and calculator.

Based on the technical aspects of the learning process, all activities can be implemented although in terms of time some of the activities of the implementation time is not in accordance with the initial planning targets. This happens because the computers used by each student have different specs and limited internet connections, so some students (about 30%) experienced a long delay to run a program when they tried. Moreover, there are some students (about 10%) whose program cannot run at all, because the computer spec does not support to run the Snap! App.

Beside the evaluation the learning process, we did observations during the process. The following results are obtained.

1. Student's attention to learning

In the entire section of learning, mostly the students focused their attention on learning. They did the task immediately, and their movements were serious. Approximately 30 students lost focus early in the learning process, as they panicked when they saw their friend was able to run the program while he or she could not yet.

2. Student interest in lessons
   As they begin to engage in learning and try to run the program, they did not stop working and enjoying the learning process. When they managed to do the task successfully, their faces were beaming. But there are some students who due to delay in running the program, they become restless even as if not interested, but these were only a small fraction of the students.

3. Student activity
   Almost all students look passive, there were no students taking notes, and they did not immediately respond when asked. However, when approached by instructor, they were asked if there are things they do not understand.

4. Eager to learn
   When learning is about to begin, some students did not enter the room immediately.

5. Learning atmosphere
   Even the class sound crowded by students chattering, but no students are downstream while studying (See Fig 6).

**Fig 6.** Learning Atmosphere

6. Circumstances of orderly learning.
   Some students who cannot run the application on their computers, join their friends. Nevertheless, learning activities are still running in an orderly manner, they take turns trying and asked to take turns if they did not understand.

**Students Feedback.** Some of feedback given by the students as follow:

1) Creating a more compatible program/use a software version which compatible with any laptop
2) Teaching slowly and giving instruction properly
3) Using colorful background in the AI guide
4) Manual book needed in the learning process
5) Making a desktop app
6) Automatic language setting
7) Deal with many objects that are in the image background
8) AI should be able to recognize what the human instructs (accuracy of the introduction of the object can be improved), when many objects are on the background.
9) Make apps that not need require an internet connection

### 4.2 Discussion

Introducing something new that actually people are used to interact with this is a challenging task. In this case, artificial intelligence is not just about the product such as robot or other sophisticated technology. People may know about AI by understanding its concepts that involve agent environment, agent perception, and agent action. What we write in this paper is a report about the learning process to give students as participant enjoyable AI programming experience therefore they can construct their understanding about AI. However, as the initial step, this result still needs some improvements.

Based on the results, there are some aspects which must be considered in the learning process, especially with children as the participants. First, using block-based programming is helpful to increase students' confidence to program AI. Snap! provides an Integrated Development Environment (IDE) which are suitable for children, easy to use but still reliable to make simple programs to complex programs. The good point is that they can create their own block, the children can feel free to explore their logic. Second, ecraft2learn gives instruction to introduce AI to children systematically. We agree that providing learning media which consists of clear article, example, and instruction can improve computational thinking of children. Both Snap! and ecraft2learn project use cloud service which facilitate to organize the workshop. However, some technical problem existed and can also occur in other developing country caused by internet connection problem, inadequate infrastructure, and communication language differences. Finally, AI programming by children using Snap! Block Programming has been quite successful to introduce AI to Indonesian Children.

## 5 Conclusion

This paper reports the result of workshop AI Programming for Children that has been done in Indonesia, involving 40 Senior High Schools and Vocational students between the 16 and 17 years old. Based on the students' answers, we can conclude that 95% of students are accustomed to using AI applications but 87.5% students confess that they

did not know about AI before. After the learning process, as many as 77.5% students can answer the question which indicates their understanding about AI. In spite of only 87.5% students that have programming experience, but almost all students enjoy the learning process (97.5%). Using Snap! and ecraft2learn contribute to the current result which shows that more than half students express the ease-of-use for both speech synthesis and machine learning. Moreover, to improve the current result, we need to investigate some problems such as technical problems, time allocation for each session, or learning method as our future work.

## 6 Acknowledgment

The authors of this article would to thank to students, teachers of SMKN 2 Cimahi, SMK Pelita, SMAN 27 Bandung, assistants (Teddy, Makhrus, Aldo) to make it possible to conduct this study with their enthusiastic cooperation. This research was supported by Department of Computer Science Education Universitas Pendidikan Indonesia and Department of Education, University of Oxford, United Kingdom. We are thankful to Direktorat TIK Universitas Pendidikan Indonesia who facilitated the use of the computers. The eCraft2Learn project is funded by the European Union's Horizon 2020 Coordination & Research and Innovation Action under Grant Agreement No 731345.

## References

1. FA Lisi and F Esposito. An AI Application to Integrated Tourism Planning. Congress of the Italian Association for Artificial Intelligence pp 246-259. (2015).
2. DS Touretzky and C Gardner-McCune. Calypso for Cozmo: Robotic AI for Everyone. Proceedings of the 49th ACM Technical Symposium on Computer Science Education Pages 1110-1110. (2018).
3. N Hatwar, A Patil, and D Gondane. AI BASED CHATBOT. International Journal of Emerging Trends in Engineering and Basic Sciences (IJEEBS), Volume 3, Issue 2 (March-April 2016), PP.85-87. (2016).
4. D Chen, J Bolton, CD Manning. A thorough examination of the cnn/daily mail reading comprehension task.arXiv preprint arXiv:1606.02858. (2016).
5. K Kahn. Three Interactions between Al and Education. Machine Intelligence. (1977).
6. W Wood and D Rünger. Psychology of Habit. Annual Review of Psychology. (2016).
7. SJ Russell and P Norvig. Artificial intelligence: a modern approach. (2016)
8. D Weintrop and U Wilensky. To block or not to block, that is the question: students' perceptions of blocks-based programming. Proceedings of the 14th International Conference on Interaction Design and Children pp 199-208. (2015).
9. K Kahn and N Winters. Child-Friendly Programming Interfaces to AI Cloud Services. European Conference on Technology Enhanced Learning pp 566-570. (2017).
10. J Figueiredo, FJ García-Peñalvo. Improving Computational Thinking Using Follow and Give Instructions. Fifth International Conference on Technological Ecosystems for Enhancing Multiculturality (TEEM'17) (Cádiz, Spain, October 18-20, 2017) (Article 3). New York, NY, USA: ACM. doi:10.1145/3144826.3145351. (2017).

11. Chovanová, AI Korshunov, and D Babčanová. (2015). Impact of Brand on Consumer Behavior. Procedia Economics and Finance 34 615 – 621. ( 2015 )
12. Kahn, K. A Logo natural language system. Technical report, MIT AI Lab, LOGO Working Paper 46. (1975)
13. Wolfram, S. An Elementary Introduction to the Wolfram Language, Second Edition. Wolfram Media. (2017a)
14. Resnick, M., Maloney, J., Monroy-Hernandez, A., Rusk, N., Easrmond, E., Brenan, K., Millner, A., Rosenbaum, E. Silver, J., Silverman, B., and Kafai, Y. Scratch : Programming for All Communication of the ACM, vol 52, no 11, pp 60-67 (2009)
15. Harvey Brian, Jens Monig. Bringing "No Ceiling to Scratch : Can One Language Serve Kids and Computer Sciences?". Constructionism. Paris. (2010)
16. Kahn K. AI Programming by Children. (2018)
17. Bagarukayo Emily. An Approach to Learning by Construction. International Journal of Education and Development using Information adn Communication Technology (IJEDICT). Vol 8, Issue 3, pp.43-61. (2012)
18. Brown, B. Taxonomy of Educational Objectives, Handbook 1 : The Cognitive Domain. New York: Davis McKay Co. Inc. (1989)
19. Andriessen Jerry., Jacobijn Sandberd. Where is Education Heading and How About AI. International Journal of Artificial Intelligent in Education, 10. 130-150. (1999)
20. M. Yoshiaki., Yoshiki Tanaka, Sanshiro Sakai. Measuring an Impact of Block-Based Language in Introductory Programming. International Federation for Information Processing. Pp.16-25. (2016).
21. Lewis, C . What do students learn about programming fro game, music video, storytelling projects? In: proceedings of the 43rd ACM Technical Symposium on Computer Science Education (SIGCSE) pp. 643-648 (2012)
22. Ozoran, D. Cagiltany, N. Topalli, D. Using scratch in introduction to programing course for engineering students. 2nd International engineering Education Conference, (IEEC) pp. 125-132 (2012)
23. Coffman, W.E. On the validity of essay tests of achievement. Journal of Educational Measurement, 3, 151-156. Google Scholar, Crossref. (1966).
24. Creswell, J.W., and V.L. Plano Clark. Designing and conducting mixed methods research. Thousand Oaks, CA: Sage Publications. (2007).
25. Borrego, M., Douglas, E. P., & Amelink, C. T. Quantitative, qualitative, and mixed research methods in engineering education. Journal of Engineering education, 98(1), 53-66. (2009).
26. Morse, J. M. Principles of mixed methods and multimethod research design. Handbook of mixed methods in social and behavioral research, 1, 189-208. (2003).
27. Papert, S., Solomon, C. Twenty Things to Do with a Computer, MIT AI Lab, http://hdl.handle.net/1721.1/5836. (1971)